

## TIRE PRESSURE MONITORING SENSOR DIAGNOSIS VIA VEHICLE ANTITHEFT AND ENTRY SYSTEM

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

5                   The present invention relates to a system and a method for tire pressure monitoring sensor diagnosis via a vehicle antitheft and entry system.

#### 2. Background Art

                  Conventional automotive industry remote keyless entry (RKE) approaches have been implemented to communicate with a vehicle through the use  
10                  of a hand held transmitter. The hand held transmitter is commonly implemented in connection with a key fob. Currently available conventional RKE transmitters may be separate units (i.e., key fobs), or the RKE transmitter assembly may be part of an ignition keyhead, preferably along with a vehicle immobilization transponder. Such RKE key fobs and keyheads generally utilize an antenna to transmit radio  
15                  frequency (RF) signals to a vehicle in order to lock or unlock vehicle doors, open or close a vehicle sliding door, unlock a vehicle trunk, activate internal and/or external vehicle lights, and/or activate a "panic" alarm. Remote access systems using such RKE fobs and keyheads typically employ on-off keying (OOK) or amplitude shift keying (ASK) modulation schemes for the RF signals.

20                  Conventional approaches for wireless monitoring of vehicle tire parameters, particularly tire pressure have been implemented. An exemplary tire monitoring system is described and shown in U.S. Patent Nos. 5,600,301 and 5,463,374, which also describes a vehicle remote access device. In such tire monitoring systems, RF transmitters mounted inside each tire, typically adjacent the  
25                  inflation valve stem, transmit information concerning tire pressure to a receiver located on-board the vehicle. The information delivered by the RF signals from the transmitters is subsequently conveyed to a vehicle operator, typically in the form of a display. Like conventional vehicle remote access systems, such conventional tire

monitoring systems also typically employ OOK or ASK modulation schemes for the RF signals. When such modulation schemes are used, however, there can be strong adverse effects on reception of the RF signal, because the amplitude of a signal transmitted from a rotating tire can vary significantly during the period of the transmission.

Conventional vehicle immobilization approaches, in order to deter vehicle theft, are also known in the automotive industry. U.S. Patent No. 5,670,933 illustrates an example of such an immobilization system. Such vehicle anti-theft devices typically employ low frequency (LF) transponders in a vehicle ignition keyhead. In such systems, upon insertion of the vehicle ignition key into the vehicle ignition keyhole, an interrogation signal is sent (i.e., transmitted, broadcast, presented, etc.) by the vehicle. In response, the keyhead transponder transmits an encrypted code to a control unit, such as a microprocessor, on-board the vehicle. When the code sent by the transponder is valid (i.e., the control unit authenticates the received code), the control unit generates a signal operative to permit the vehicle to be activated. However, when the code is not received by the control unit, or when the code is not valid (i.e., the control unit cannot authenticate the received code), the control unit generates a signal operative to immobilize the vehicle, for example, by cutting off power to the fuel supply for the vehicle engine.

Conventional approaches for shared vehicle remote access, tire monitoring and vehicle immobilization are also known in the automotive industry. U.S. Patent No. 6,420,967 illustrates an example of such an immobilization system. Such a system and method employs a combined RKE, tire monitoring and vehicle immobilization receiver and a single microprocessor controller. Such a system and method uses an OOK or ASK modulation scheme for RKE, while employing frequency shift keying (FSK) modulation scheme for tire monitoring. Still further, such a system and method provides an RF link for implementation in the vehicle immobilization.

A number of conventional vehicle TPM systems implement an existing RF interface (e.g., an RKE interface) to the TPM receiver. Increasingly,

conventional vehicle TPM systems implement LF command signals. A number of conventional TPM sensors implement an LF command interface that is configured to provide sensor testing and diagnosis. The LF command interface is typically implemented such that the TPM sensor manufacturer and service personnel (e.g.,  
5 vehicle dealership personnel, etc.) using specialized (sometimes vehicle specific) tools can perform the TPM sensor testing and diagnosis during manufacture, retrofit, replacement, etc. operations without the service personnel mounting the TPM sensor in a wheel assembly and mounting the wheel assembly on the respective vehicle prior to the testing and/or diagnosis. The TPM sensor testing and diagnosis  
10 can be performed without having to mount the TPM sensor in a wheel and mount the wheel on a vehicle via the specialized equipment that is available to the TPM sensor manufacturer and authorized service personnel such as vehicle dealership personnel.

However, when personnel other than dealership mechanics or  
15 manufacturer technicians have a need to determine if a TPM sensor is working properly, the TPM sensor typically must first be installed in the wheel assembly, the wheel assembly is balanced, then the wheel is installed on the vehicle. The vehicle TPM system is then operated in a test mode to determine TPM sensor operation. However, when the TPM sensor is not working properly (e.g., due damage from  
20 a flat tire, or the like), a significant amount of time and cost are expended prior to determination of proper TPM sensor operation. When the TPM sensor does not work properly and must be repaired or replaced, the time and cost are wasted.

Thus, there exists a need and an opportunity for a system and a method to quickly perform TPM sensor test and diagnosis before the TPM sensor  
25 is fastened to a wheel and the wheel is installed on a vehicle. Such a system and method may implement a new and innovative TPM sensor test and diagnosis, and result in the saving of a significant amount of time and cost when compared to conventional approaches to TPM sensor test and diagnosis.

## SUMMARY OF THE INVENTION

The present invention generally provides an improved method and an improved system for tire pressure monitoring (TPM) sensor testing and diagnosis via a vehicle antitheft and/or entry system. Such a system and method may  
5 implement a new and innovative TPM sensor test and diagnosis, and result in the saving of a significant amount of time and cost when compared to conventional approaches to TPM sensor test and diagnosis.

According to the present invention, a vehicle tire pressure monitoring (TPM) system is provided. The system comprising an immobilizer transmitter, at  
10 least one TPM sensor, and a TPM receiver. The immobilizer transmitter transmits at least one low frequency (LF) sensor diagnostic signal. The at least one TPM sensor comprises a transceiver that receives the at least one LF sensor diagnostic signal and, when the at least one TPM sensor is operating properly, presents at least one radio frequency (RF) message signal. The TPM receiver receives the at least  
15 one RF message signal and provides an indication to an operator when the at least one RF message signal is received, wherein the LF sensor diagnostic signal is transmitted to determine proper operation of the at least one TPM sensor.

Also according to the present invention, for use in a vehicle tire pressure monitoring (TPM) system, a method of determining proper operation of a  
20 TPM sensor is provided. The method comprising transmitting at least one low frequency (LF) sensor diagnostic signal via an immobilizer transmitter, providing at least one TPM sensor, wherein of the at least one TPM sensor comprises a transceiver that receives the at least one LF command signal and presents at least one radio frequency (RF) message signal, presenting the RF message signal when  
25 the at least one TPM sensor is operating properly, and providing an indication to an operator when the at least one RF message signal is received by a TPM receiver.

Further, according to the present invention, a vehicle tire pressure monitoring (TPM) system having self-diagnostics is provided. The system comprising an immobilizer transmitter, at least one TPM sensor, and a combination

remote keyless entry and TPM receiver. The immobilizer transmitter transmits at least one low frequency (LF) sensor diagnostic signal. The at least one TPM sensor comprises a transceiver that receives the at least one LF sensor diagnostic signal, and presents at least one radio frequency (RF) message signal in response to the LF  
5 sensor diagnostic signal when operating properly. The combination remote keyless entry and TPM receiver receives the at least one RF message signal and provides an indication to an operator when the at least one RF message signal is received and an alert to the operator when the at least one RF message signal is not received.

The above features, and other features and advantages of the present  
10 invention are readily apparent from the following detailed descriptions thereof when taken in connection with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a diagram of a tire pressure monitoring system of the present invention; and

15 FIGURE 2 is a flow diagram of an operation of the tire pressure monitoring system of FIGURE 1.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

With reference to the Figures, the preferred embodiments of the present invention will now be described in detail. Generally, the present invention  
20 provides a system and a method for tire pressure monitoring sensor diagnosis. In one example, the improved method and system may be implemented in connection with or via a vehicle anti-theft and entry system.

The present invention may implement vehicle immobilizer, remote keyless entry (RKE), and/or tire pressure monitoring (TPM) receiver systems to  
25 incorporate TPM sensor test and diagnosis capability, that is not available in

conventional approaches (e.g., via novel and improved control software). The present invention may provide for implementation of a vehicle anti-theft immobilizer system to read, command, and control a TPM sensor when the TPM sensor is placed nearby the vehicle anti-theft immobilizer system, and for response via a vehicle RKE system, such that sensor testing, diagnosis, teaching the TPM sensor to the vehicle or a particular location on the vehicle, and the like may be performed without implementation of specialized equipment as is implemented in conventional approaches.

The present invention may provide a TPM system and method having self-diagnostics. The present invention may provide for implementation of a simple apparatus and technique (i.e., a system and a method) for an owner or independent mechanic to determine when a TPM tire sensor is faulty, to aid in the diagnosis of a faulty TPM sensor and/or TPM system, teach new/alternative sensors to the TPM system, etc. The present invention may be implemented in connection with vehicle immobilizer, TPM, and RKE systems and methodologies. The present invention may result in the saving of a significant amount of time and cost when compared to conventional approaches to TPM sensor test and diagnosis.

Referring to Figure 1, a diagram illustrating a tire pressure monitoring (TPM) system 100 in accordance with the present invention is shown. The TPM system 100 generally comprises an immobilizer circuit (i.e., unit, apparatus, transmitter, transceiver, etc.) 102, at least one TPM sensor 104, and a TPM, remote keyless entry (RKE), or combination TPM/RKE circuit (i.e., receiver, apparatus, unit, transmitter, transceiver, etc.) 106. The system 100 is generally implemented in connection with a vehicle (not shown, e.g., automobile, truck, sport utility vehicle, mini-van, full-sized van, etc.) having a number of wheel assemblies (not shown). The wheel assemblies generally comprise at least one tire mounted on a rim where the tire is inflated with a gas (generally air). The system 100 may be implemented as a TPM system having self-diagnostics.

The TPM system 100 is generally implemented to monitor at least air pressure inside the at least one wheel and provide information to a user (or operator)

regarding the tire pressure. For example, the TPM system 100 may provide at least one alert signal (e.g., an audible warning, a visual warning such as a flashing LED, etc.) when an anomalous operating condition such as tire under inflation or an over inflation is detected. Other anomalous operating conditions such as tire over  
5 temperature conditions, loss of TPM sensor signal, etc. may also be reported by the system 100. The system 100 may provide the user an indication of a particular wheel that experienced the anomalous operating condition.

The immobilizer 102 may be implemented in connection with a vehicle anti-theft (or theft deterrent) system. In the present invention, the  
10 immobilizer 102 may be configured (or controlled) to present at least one LF command (e.g., TEST). The signal TEST is generally implemented as a TPM sensor diagnostic signal. The signal TEST may be implemented as a TPM system diagnostic signal. The signal TEST is generally presented in connection with operations such as a TPM sensor operation test, a TPM sensor diagnosis, a TPM  
15 system diagnosis, a TPM sensor teaching (or association) to the TPM system, a TPM sensor location teaching (or association) on the vehicle within the TPM system, and the like, independently of vehicle immobilization operation.

The immobilizer 102 is generally further configured to present (i.e., transmit, broadcast, send, etc.) at least one low frequency (LF) command (i.e.,  
20 signal) in connection with vehicle theft deterrent. Such a vehicle theft deterrent command may be a signal that is presented to disable a vehicle fuel pump, enable an alarm, disable a vehicle powertrain control module (PCM), etc.

The at least one TPM sensors 104 generally each comprise an assembly (i.e., module, apparatus, etc.) having a unique identification code or other  
25 appropriate identifier and including at least one sensing device (not shown) that is configured to determine an appropriate physical condition (e.g., gas pressure, temperature, etc.), an antenna 110 that is configured to receive and present a number of signals wherein the signals may be broadcast at any appropriate frequency (e.g., low frequency, LF, radio frequency, RF, etc.) and via any  
30 appropriate protocol (e.g., on-off keying (OOK), amplitude shift keying (ASK), or

frequency shift keying (FSK) modulation, etc.) coupled to a sensor transceiver (not shown), and the sensor transceiver is coupled to the at least one sensing device and configured to receive and transmit the appropriate signals.

5 A target (i.e., a particular) one of the at least one TPM sensors 104 is generally positioned (i.e., placed, set, located, disposed, etc.) near the vehicle where the LF immobilizer 102 is implemented at or near the normal operation location. When the sensor 104 is to be tested for functionality, the sensor 104 may be placed at any appropriate location on, in or near the vehicle. However, the sensor 104 may be located at any appropriate location to meet the design criteria of a particular application.

When the particular (or target) TPM sensor 104 receives the signal (or command) TEST, the sensor 104 generally presents an message (or signal), (e.g., RECD). The sensor 104 is generally configured to present the signal RECD in response to the signal TEST. The message signal RECD is generally  
15 implemented as an RF signal in connection with an RKE system of the vehicle where the TPM system 100 is implemented.

The signal RECD generally comprises information (or data) that indicates that the signal TEST was properly received by the target TPM sensor 104 and that the TPM sensor 104 is operating properly. The signal RECD may further  
20 comprise information that provides an indication that the sensor 104 is operating properly, however, not at a location that can be particularly located, etc. The signal RECD may further comprise information regarding the unique identifier for the target sensor 104. The message signal RECD may further comprise information that provides the system 100 an indication of proper operation one or more of the at least  
25 one sensing devices that comprise the TPM sensor 104.

In one example, the receiver 106 may be implemented as a TPM RF receiver. The receiver 106 is generally implemented as a combination RKE and TPM RF receiver. As such, the receiver 106 generally provides at least one RKE operation as well as at least one TPM operation. However, the receiver 106 may



be implemented as any appropriate receiver to meet the design criteria of a particular application. The receiver 106 generally receives the signal RECD and provides the user (or operator) an indication of the information that may be contained in the signal RECD (i.e., the circuit 106 is generally configured to provide the user at least one indication of TPM sensor (e.g., sensor 104) operation in response to the signal RECD). For example, the receiver 106 generally provides an indication (e.g., a visual and/or audible signal) when the signal RECD is received, and an alert (e.g., a visual and/or audible signal) when the signal RECD is not received in response to transmission of the signal TEST.

Thus, the user is generally provided the information that the sensor 104 is operating properly (or not operating properly), and, for example, the TPM sensor 104 may be installed on a wheel prior to the installation of the wheel on the vehicle with reduced concern for wasted time. The receiver 106 may be further configured to provide the operator additional information that may be contained in the at least one signal RECD (e.g., location of the sensor 104, proper operation or failure of proper operation of the at least one sensing devices that comprise the sensor 104, etc.). The signal RECD may "teach" (i.e., relate, associate, etc.) the sensor 104 identifier to the system 100.

Referring to Figure 2, a flow diagram illustrating an operation (e.g., method, process, routine, commands, steps, blocks, etc.) 200 in accordance with the present invention is shown. The operation 200 is generally implemented as a method that may provide for command and control of a vehicle anti-theft immobilizer system to a TPM sensor when the TPM sensor is placed nearby the vehicle anti-theft immobilizer system, and for response via a vehicle TPM, RKE, or combination TPM/RKE system, such that sensor testing, diagnosis, teaching the TPM sensor to the vehicle, associating the sensor 104 identification code to the system 100, or a particular sensor location on the vehicle, and the like may be performed without implementation of specialized equipment as is implemented in conventional approaches. The method 200 may be implemented in connection with a TPM system such as the system 100. However, the method 200 may be

implemented in connection with any appropriate TPM system to meet the design criteria of a particular application.

5 An operator (e.g., user, owner, technician, mechanic, etc.) may activate (i.e., initiate, start, begin, etc.) the process 200 (step or block 202). The process 200 may be initiated when the user desires to test the operation of a target (i.e., a particular) TPM sensor, associate a TPM sensor to a particular vehicle location, perform diagnosis on a TPM sensor, perform diagnosis on a TPM system (e.g., via implementation of a known good TPM sensor), associate a unique sensor 104 identifier to a vehicle TPM. RKE, or combination TPM/RKE system, etc., and 10 the user does not have available the specialized equipment that is implemented in connection with conventional approaches to such processes. The step of activating the process 200 (i.e., step 202) generally includes positioning a TPM sensor (e.g., at least one TPM sensor 104, generally a target one of the TPM sensors 104), at a desired location such as at or near (i.e., nearby) a normal operating position on the 15 vehicle where the process 200 is implemented. The operator generally initiates the process 200 independently of vehicle immobilization operation.

20 An LF command or TPM sensor/system diagnostic signal (e.g., the signal TEST) may be presented by an immobilizer transmitter (e.g., the immobilizer 102) (step or block 204). The process 200 may be implemented to determine whether the signal TEST was received by the target TPM sensor and the TPM sensor presented (i.e., transmitted, sent, broadcast, etc.) a message that indicates the TPM sensor is operating properly (e.g., the signal RECD) to a RKE/TPM receiver (e.g., the receiver 106) (decision step or block 206).

25 When the signal RECD is received and the target TPM sensor is operating properly (i.e., the YES leg of decision block 206), the receiver (e.g., the receiver 106) generally provides the operator an indication that the TPM sensor is operating properly (e.g., the signal RECD is presented by the target one of the at least one TPM sensor 104) and an indication is presented to the operator (step or block 208). In one example, the receiver implemented in connection with the 30 process 200 may further (i.e., optionally) provide the operator additional

information (or data) such as an indication of the location of the TPM sensor (e.g., right front tire, left rear tire, spare tire, etc.), information that the TPM sensor is properly operational, however, not at a location that can be particularly located, an indication of proper operation one or more of the at least one sensing devices that  
5 comprise the TPM sensor, association (or “teaching”) of a unique sensor 104 to the system 100, and the like (step or block 210).

Returning to the decision step 206, When the signal RECD is not received (i.e., the NO leg of the decision block 206), an alert is generally presented to the operator (e.g., via the receiver 106) (step or block 212). The alert generally  
10 provides an indication that the target TPM sensor did not respond (e.g., the signal RECD was not presented in response to transmission of the signal TEST) within a predetermined time interval. The operator may take steps for diagnosis, repair, replacement, etc. for the TPM sensor and/or other elements of the TPM system (e.g., the immobilizer 102, the receiver 106, etc.) without having expended  
15 significant time and cost associated with mounting the TPM sensor in a wheel assembly, and mounting the wheel assembly on the vehicle, and testing the TPM sensor operation as is performed in conventional approaches.

As is readily apparent from the foregoing description, then, the present invention generally provides an improved system (e.g., the system 100) and an  
20 improved method (e.g., the method 200) for tire pressure monitoring sensor diagnosis via vehicle anti-theft (e.g., immobilizer) systems and/or entry (e.g., TPM, RKE, or combination TPM/RKE) systems. Such a system and method may provide a new and innovative TPM sensor test and diagnosis, and result in the saving of a significant amount of time and cost when compared to conventional approaches to  
25 TPM sensor test and diagnosis.

While embodiments of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes  
30 may be made without departing from the spirit and scope of the invention.